[redacted]

2 January 1964
LEG:mb-1

Chief, Office of Naval Research
Department of the Navy
Washington 25, D. C.

Attention: Code 414, [redacted]

Subject: [redacted]
Perception Concepts to Photo-Interpretation

Enclosure: Nine Copies of Letter Report No. 22

Dear Sir:

We are enclosing nine copies of Letter Report No. 22 covering our technical progress under Contract [redacted] during November 1963.

Of the contract estimated cost as amended by Modification #6 amounting to [redacted] we have expended [redacted] as of 1 December 1963, leaving a balance of [redacted]

[redacted]

Approved For Release 2005/05/02 : CIA-RDP78B04770A002300030026-7

STAT

[redacted]

Letter Report No. 23

<u>Investigation of Perceptron Applicability to</u>

<u>Photo Interpretation</u>

[redacted]

STAT

Monthly Letter Report

for the month of December 1963

[redacted]

STAT

[redacted] STAT

STAT [redacted] Report No. 23

Letter Report No. 23

Investigation of Perceptron Applicability to Photo Interpretation

Monthly Letter Report
for the month of December 1963

1.0 INTRODUCTION

Project PICS is an investigation of the applicability of perceptrons to automation of certain parts of the photo interpretation task. Particular emphasis is placed on area and object recognition based upon properties derived from two-dimensional power spectra. Accordingly, effort is centered in the following major areas:

1) Theoretical and experimental evaluation of the properties which can be derived by optical spatial filtering.
2) Design and implementation of a recognition system based upon such properties.
3) Design of optical-electronic spatial filtering equipment.
4) Research based upon ideas whose immediate applicability cannot be stated, but of potential long-term benefit.

2.0 ACTIVITY AND ACCOMPLISHMENTS DURING DECEMBER 1963

2.1 Project Review

Two meetings with sponsoring agency personnel occurred:

[redacted] STAT

Their chief purpose was to review progress on the design of optical-electronic spatial filtering equipment, and to discuss the application of coherent optics to photo-interpretation.

2.2 Property Evaluation

No work on spectral property evaluation was done in December.

2.3 Design of Optical-Electronic Spatial Filtering Apparatus

The optical portions of the filtering apparatus were set up in the clean room during December. The first set-up early in December used an Osram 100 watt mercury (5460 Å) source, a 1/8 millimeter pinhole, collimator and object lenses, a liquid gate holding the test transparencies, and a Kintel television system with a standard 7735-A vidicon.

The first set-up provided strong display signals from standard test patterns and half-tones, but the luminance levels at high spatial frequencies were marginal for photographs. The total power in the collimated light beam directed through the objective transparency was measured to be about 0.25 microwatt.

Even with the marginal light levels, the brightness of the central (low-frequency) spot on the vidicon was sufficient to damage the tube. This is indicative of the dynamic range problems imposed on pickup devices in the frequency plane.

A second set-up in mid-December (nearly identical to the first) was demonstrated during the project review meeting. To reduce the dynamic range at the vidicon, and thus allow more vidicon sensitivityto be used, a small central disk occluder was used at the frequency plane. This was then imaged on the vidicon sensitive surface. The conclusion of usually-inadequate light level was reached as before, although some high frequency structure was visible on the TV monitor for strong object-transparency features.

In a working system, a variable density, circularly symmetric filter designed to strongly attenuate, but not completely block, the low frequency signal would be used. Thus the dynamic range would be reduced, but the ability to obtain data everywhere in the spectrum would be maintained. Such a filter is called a "pre-whitening" filter.

Preliminary design of electronic circuity which will produce the desired types of integration areas in the frequency plane was completed during December. Special purpose logic equipment of conventional design, driven from comparators which use functions of the raster-scan sweep voltages as inputs, is used to derive a video gating signal during the time that the vidicon read-out beam is interrogating the desired raster areas. A wide variety of interesting area shapes and sizes are readily accomodated by this design.

The only unusual electronic design problem is that presented by the necessity to remove the attenuation inserted by the pre-whitening filter. A wide-bandwidth variable-gain amplifier is required.

2.4 Recognition Studies

The ordinary viewpoint of the weight derivation (training) process of a perceptron is that of moving a plane in the binary n-space defined by the A-unit activities, such that the members of two classes are separated. Several new insights into the problem are available if one considers the dual problem. That is, we define the space of interest by the A-unit weights. In this space, each stimulus is a hyper-plane and a set of weights is a point. A solution is represented by any point within a convex region determined by the stimulus planes and their required classification.

Because of the convexity of the solution region (if it exists) many properties of the set of solution are immediately apparent. For example, given W_1 and W_2 any two weight vectors which are solutions, then $aW_1 + (1-a)W_2$ is also a solution for all $1 \leq a < 0$.

Using these new (to perceptron theory) concepts a new method of training was postulated. It depended upon successive relaxation of the boundaries of the solution region, followed by a step toward the interior of the region. Several trial examples showed that no simple method known to the experimenters will yield a step toward the interior of the region when the current trial point is at a vertex of order higher than two. Since this is an extremely likely event at an early stage in the solution, work on this particular training method has been suspended.

It is expected that the really very fruitful dual viewpoint may yield additional new techniques for trial. A particular problem that may well be attacked from this outlook is that of effective discovery of training problems which have no perfect solution. We also hope to shed some light on the multiple solution problem.

3.0 PLANS FOR JANUARY 1964

3.1 Design of Optical-Electronic Spatial Filtering Apparatus

During January 1964 the following are expected to be accomplished:

1) Operation of a clean room mock-up using a gas laser in the visible red (6328Å) as a light source. This experiment would

investigate the increase in brightness and coherence apparently available from a laser source, and indicate problem areas (reflections, mechanical alignment, lens quality) emphasized by this type of source.

2) Preparation of a memorandum describing the filtering apparatus experiments, results to date, and conclusions.

3.2 Recognition Studies

Continued investigation of the training problem from the dual viewpoint are planned.

4.0 REPORTS

No reports other than the regular monthly letter report were due or issued during December.

24 January 1964
LEG:vg-28

Chief, Office of Naval Research
Department of the Navy
Washington 25, D. C.

Attention: Code 414, [redacted] STAT

STAT Subject: [redacted], Application of Perceptron Concepts to Photo-Interpretation

Enclosure: Nine Copies of Letter Report No. 23

Dear Sir:

We are enclosing nine copies of Letter Report No. 23 covering our technical progress under [redacted] during December 1963. STAT

STAT Of the contract estimated cost as amended by Modification #6 amounting to [redacted] we have expended [redacted] as of 31 December 1963, leaving a balance of [redacted] In terms of cumulative labor and indirect costs under the contract, the following is a summary as of 29 December 1963: STAT STAT STAT

[redacted]

STAT

File

STAT

Letter Report No. 19

Investigation of Perceptron Applicability to Photo Interpretation

STAT

Monthly Letter Report

for the month of August 1963

STAT

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STAT

[redacted]

[redacted]

Report No. 19

Letter Report No. 19

Investigation of Perceptron Applicability to Photo Interpretation

Monthly Letter Report
for the month of August 1963

1.0 INTRODUCTION

Project PICS is an investigation of the applicability of perceptrons to automation of certain portions of the photo interpretation task. Current effort is centered in four technical areas:

1) Development of techniques for whole-photo classification applicable to the rejection of sterile photographs.
2) Development of techniques for the detection and isolation of objects contained in photographs.
3) Improvement of object recognition capabilities by parametric studies of the perceptron as a two-dimensional pattern recognizer.
4) Investigation of techniques for implementing the processes under development.

2.0 ACTIVITY AND ACCOMPLISHMENTS DURING AUGUST 1963

2.1 Object Detection

The computer program for implementing a broad class of two-dimensional linear filters was completed in August, as planned. This program can be arranged to behave as any filter whose one-sided one-dimensional transfer function is expressible as a second-degree rational function in the complex frequency variable. No symmetry restrictions are imposed. At present the maximum picture size which can be accommodated by the program is 10 square inches, at a resolution of 50 samples per inch in each direction.

In order to check the operation of the program, and to provide some initial information about the behavior of the filter outputs with real inputs, three related filters were designed: low pass, high pass, and band pass. The filters are related in that their frequency domain expressions have the same poles. The one-dimensional gain vs. frequency curves for all three filters are shown in Fig. 3. The frequency scale has been adjusted to agree with the reproduction scale of the sample outputs to be discussed.

Figures 1 and 2 illustrate the results of applying these filtering processes to two picture segments. Figures 1c and 1d show the absolute value of the filter outputs, since negative numbers cannot be accommodated by the output process. A bias equivalent to a medium gray has been added to the output to produce Fig. 2b for the same reason. In all three of these photographs, the consistent areas of large output (black in Fig. 1c and 1d, black and white in Fig. 2b) in the vicinity of the objects are noteworthy.

2.2 Whole Photo Classification

The major activity so far in attacking this objective is the exploration of the results obtainable from linear filters of various kinds. Thus the computer program and sample results discussed in Section 2.1 are the principal effort here also. The result shown in Fig. 2b suggest that consistently large outputs from a properly chosen bandpass filter can be used to discriminate between picture anomalies of large size (such as ships) and those of small size (such as waves).

2.3 Recognition

The program mentioned in the last monthly letter report (No. 18) for measuring the rate at which individual A-units are transmitting information about the classification of the patterns, has been coded and check out on the IBM 704. This program prints out, for each A-unit, the transmission rate, in bits, and the average rate at which information is being transmitted for each type of A-unit, where A-unit types may vary in the number of S to A-unit connections, the ratio of excitatory to inhibitory connections, etc. As part of the checkout procedure the program was run with a set of 500 A-units being used to discriminate airplane silhouettes from those of other objects. Transmission rates for this group of A-units varied from 0 to about .38 bits per pattern. Correct classification of all patterns would require as the combined output of all A-units somewhat less than 1 bit per pattern. Because of the high variability in the transmission rates of different A-units of the same type, a fairly large number of A-units of a single type must be sampled to obtain reliable statistics of the differences between different types of A-units.

The measurements of A-unit transmission rates might be used to implement a self-organizing system which would carry out an A-unit selection scheme on two levels, first varying parameters to determine the best type or types of A-units to generate by using a "hill-climbing" technique in conjunction with the average transmission rate for the group, and then having selected a type or perhaps several types of A-units, the best individual A-units within that type could be selected. Had the transmission rates of all A-units been nearly the same, such a selection scheme might not have been beneficial; however, because of the high variability which does exist in transmission rates, such selection techniques might be extremely useful.

Another possible self-organizing technique which could either be implemented in conjunction with those just described, or separately, would be to optimize individual A-units by systematically varying their S to A-unit connections, thresholds, etc. For example, having used the previous process to select several good A-units, first generation descendants of these could be constructed which resembled the parent A-unit in all respects except that a single S to A-unit connection might be moved right, left, up or down, by one square, or the threshold moved up or down by 1. Transmission rates would then be measured for all descendants, and the best descendant in each family would be chosen. Using these a second generation of A-units could be constructed, and the same process repeated several times until little or no further improvement in transmission rates was achieved.

Any of these self-organizing techniques depend upon good correlation between the information measure for a single A-unit and the performance of an assemblage of A-units.

2.4 Implementation

Literature surveyed included reports from [redacted] and current periodicals on the following topics: spatial optical filters, photochromic effects, and recognition system implementation. The use of photochromic film as an adaptive element in a recognition system design is being evaluated. Practical details on the limitations of spatial optical filters were discussed with several of [redacted] specialists in this important area.

3.0 PLANS FOR SEPTEMBER

3.1 Object Detection

Further experiments using the filtering program mentioned in Section 2.1, and a range of filter designs are planned. The objective of these experiments will be to determine the effect of changes in filter parameters, object size and shape, in order to guide the experiments toward some practical detection procedure.

3.2 Whole-Photo Classification

The possibility suggested above, for the detection of frames having large objects by use of an appropriate band-pass filter, will be followed during September. Quantitative experiments will be carried out in order to estimate the range of validity of the idea.

3.3 Recognition

The distribution of transmission rates already obtained will be examined in more detail to determine if the present program should be modified to also print out the histogram of the distribution, the standard deviation, or some other statistics. It is planned to begin tests with different A-unit types, and to compare the average values of individual A-unit transmission rates of a particular A-unit type with the performance of a full-scale perceptron in discrimination of airplanes versus other objects, when the perceptron is constructed entirely of randomly generated A-units of the same type. The purpose of these tests is to establish that a correlation does exist between the measures of individual A-unit transmission rates, and performance of the over-all system.

3.4 Implementation

Implementation work will continue the report survey and evaluation of photochromic media and optical filter.

4.0 REPORTS

Three lectures were given by H. R. Leland at the seminar on Pictorial Data Processing held at Yeshiva University, August 19 to August 29. Although not directly a part of the project effort, these included discussion of photo interpretation techniques, including the current work in spatial filtering, a general discussion of the perceptron and related existence and convergence theorems, and current pattern recognition research based on the perceptron type of organization.

The seminar was also attended by [redacted] of the PICS staff. STAT

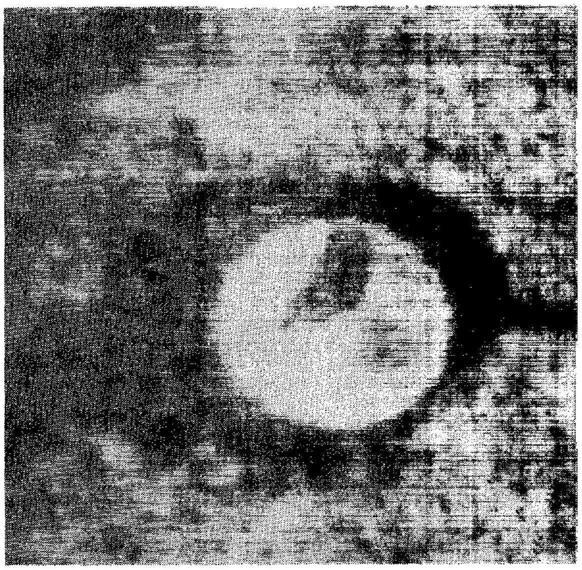


Figure la
INPUT PHOTOGRAPH

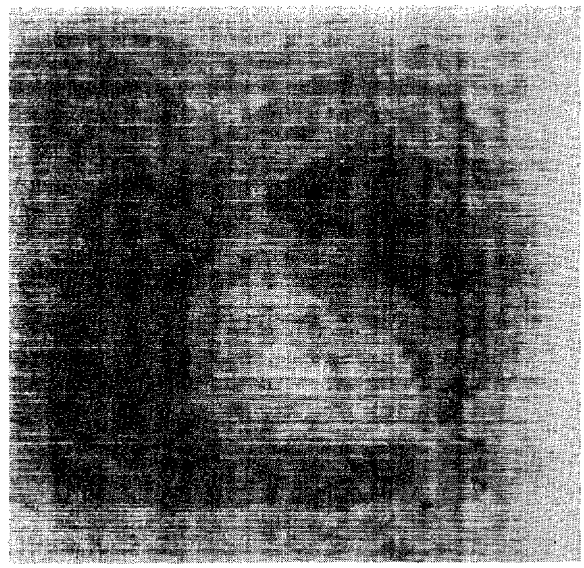


Figure lb
OUTPUT OF LOW-PASS FILTER
APPLIED TO Figure la

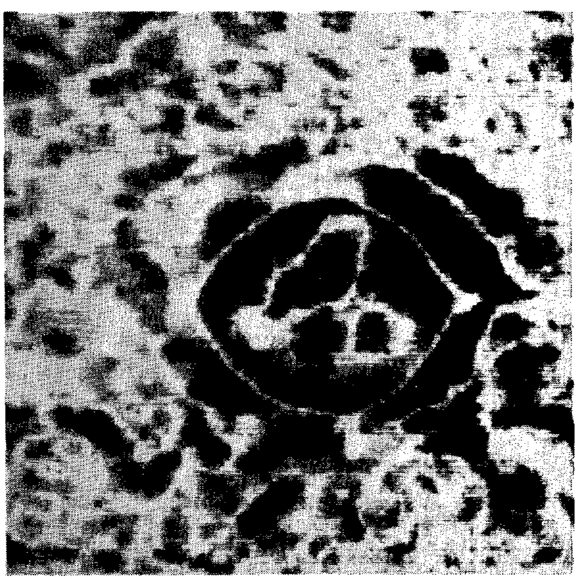


Figure lc
ABSOLUTE VALUE OF THE OUTPUT OF
HIGH-PASS FILTER APPLIED TO Figure la

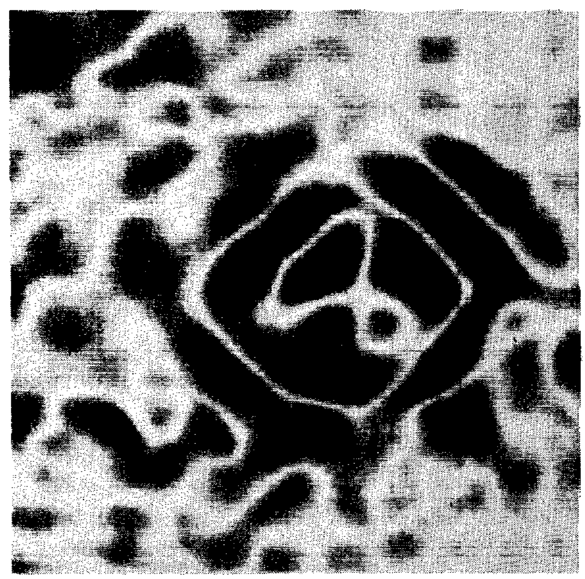


Figure ld
ABSOLUTE VALUE OF THE OUTPUT OF
BAND-PASS FILTER APPLIED TO Figure la

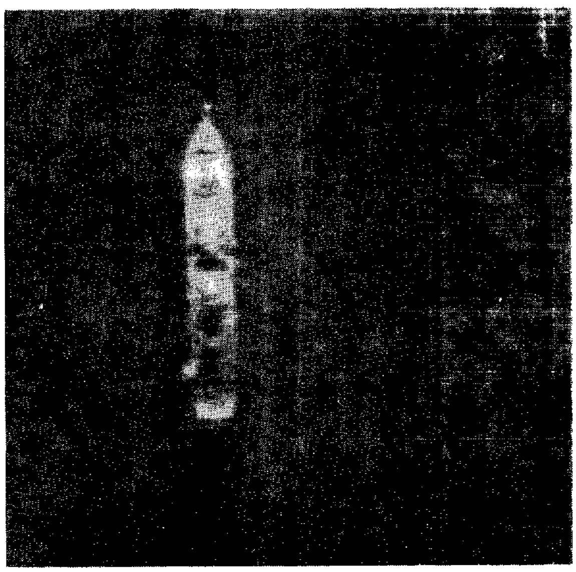


Figure 2a
INPUT PHOTOGRAPH

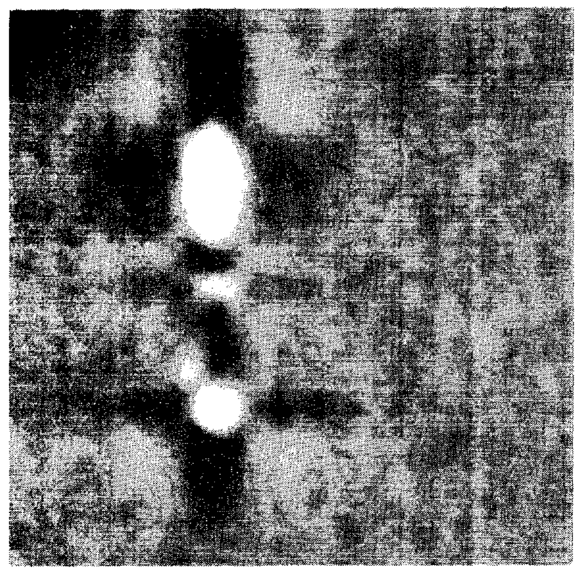
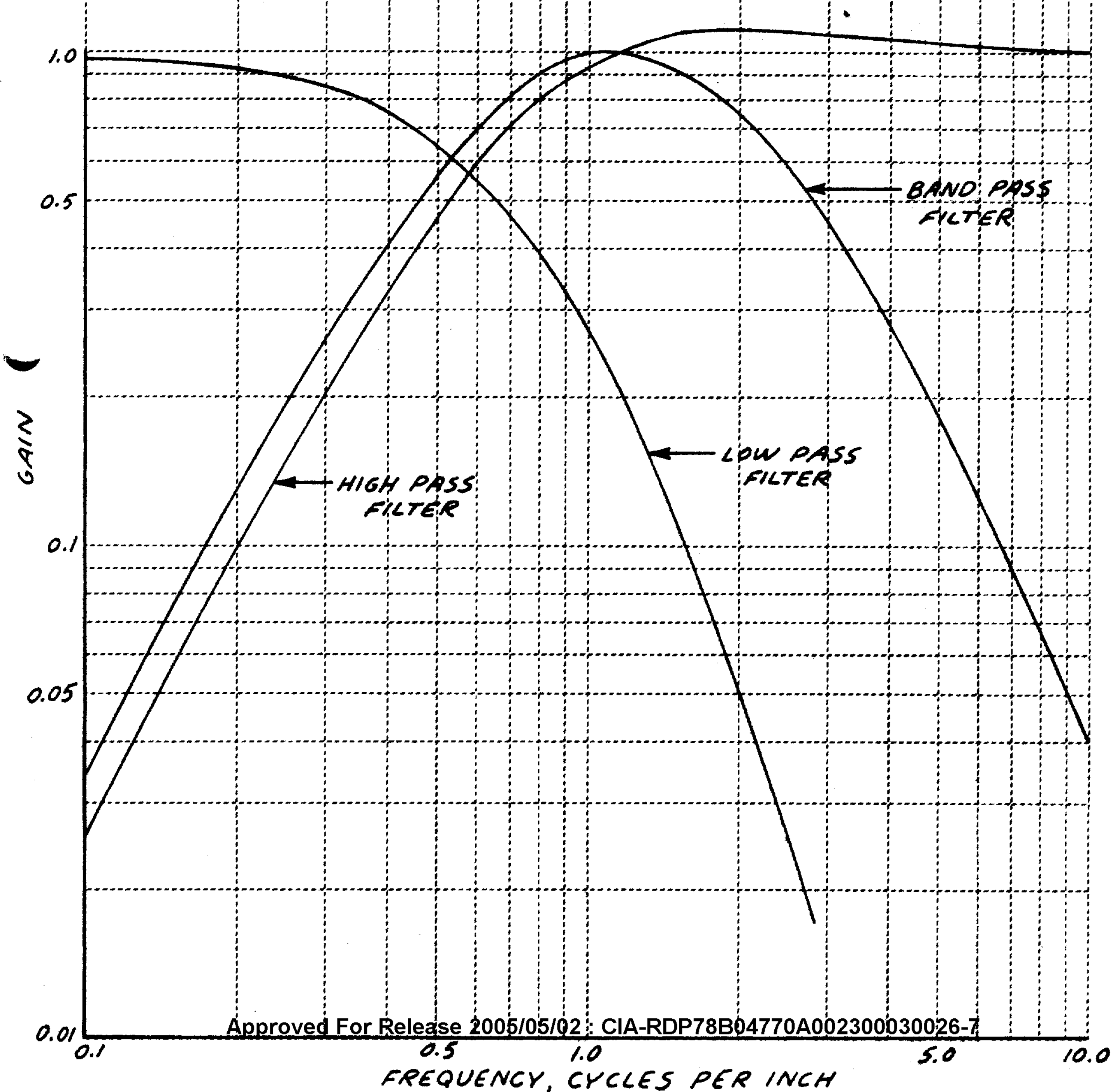


Figure 2b
OUTPUT OF BAND-PASS FILTER APPLIED
TO Figure 2a WITH BIAS ADDED

FIGURE 3 GAIN VS. FREQUENCY FOR THREE FILTERS



FILE

[redacted]

Letter Report No. 18

Investigation of Perceptron Applicability to Photo Interpretation

[redacted]

Monthly Letter Report

for the month of July 1963

[redacted]

[redacted] eport No. 18

Letter Report No. 18

Investigation of Perceptron Applicability to

Photo Interpretation

Monthly Letter Report

for the month of July 1963

1.0 INTRODUCTION

Project PICS is an investigation of the applicability of perceptrons to automation of certain portions of the photo interpretation task. Current effort is centered in four technical areas:

1) Development of techniques for whole-photo classification applicable to the rejection of sterile photographs.

2) Development of techniques for the detection and isolation of objects contained in photographs.

3) Improvement of object recognition capabilities by parametric studies of the perceptron as a two-dimensional pattern recognizer.

4) Investigation of techniques for implementing the processes under development.

2.0 ACTIVITY AND ACCOMPLISHMENTS DURING JULY 1963

2.1 Planning

A meeting was held with ONR representatives at [redacted] during June to discuss plans for the project. Ideas discussed at this meeting were incorporated into a work outline for Project PICS submitted to ONR on 5 July. This outline specifies both long-term objectives (what we eventually hope to achieve), and short-term objectives (what we can reasonably hope to achieve during the current contract period). These are listed below.

<u>Whole-Photo Classification</u>

<u>Long-Term Goal</u>: Automatic scanning of large quantities of aerial photographs to remove those which are sterile; such as photos of cloud cover, empty ocean, or those containing no works of man.

<u>Short-Term Goal</u>: Invention, analysis, and trial of at least one technique on at least one type of discrimination, such as empty ocean vs. ocean containing ships.

Recognition

Long-Term Goal: Provide recognition apparatus which will become a part of an automated photo interpretation system.

Short-Term Goal: Perform analysis and experiments leading to a better understanding of a perceptron as a two-dimensional pattern recognition device, especially with respect to trade-offs among sensory to association unit connection density, organization of these connections, and number of association units.

Object Detection

Long-Term Goal: Automatic analysis and classification of aerial photographs by means of detection and recognition of the objects which they contain.

Short-Term Goal: Invention, implementation, and test of new object detection techniques.

Implementation

Long-Term Goal: Construction of a device which can realize the long term goals of object detection and whole-photo classification as outlined above.

Short-Term Goals:

1. Identification of techniques which may be useful in performing the processes required.
2. Laboratoy investigation of one or more such techniques.

2.2 Object Detection

An available property which has not yet been exploited for object detection is the two-dimensional frequency spectrum. The concept is that the input photographs would be passed through two or more linear two-dimensional filters. Some non-linear function of the outputs of these filters (measured at each input picture point) would be used to determine whether each point should be marked as an object point.

To test the validity of this idea, a computer program is being written which will allow a very general class of filters to be implemented on the IBM-704. The basic technique is contained in a paper by [redacted] As of the end of July this program was completely written and about 75% debugged. STAT

2.3 Whole-Photo Classification

The first idea to be tested in this area will be the applicability of filters similar to those discussed in Section 2.2. It is conjectured that the two-dimensional spectrum of, for example, ocean will differ significantly from that of land. Thus the computer program mentioned above will also be used to test methods for area discrimination. STAT

[redacted]

2.4 Recognition

It is desired to gain a better understanding of the relation between the recognition ability of a perceptron and the values specified for such perceptron parameters as; 1) number of S to A-unit connections, 2) the ratio of excitatory to inhibitory connections, 3) the threshold setting of the A-unit, and 4) constraints which limit the S to A-unit connections to subregions of the retina. Perceptron implementation programs which are currently available for the IBM-704 would allow us to investigate various combinations of these parameters, but only by running a full scale test of a perceptron for each combination of parameters. Because of the large amount of computer time required by such an investigation, current effort is being devoted to determining some measure of A-unit performance which would be applicable to A-units on an individual basis, rather than in combination. Such a measure, based on the concepts of information theory, has been suggested in a paper by Lewis[2]. This measure gives, in effect, the rate at which an A-unit is transmitting information about the classification of the pattern, and makes use of the joint probability distribution of A-unit activity and pattern classification. It is hoped that high transmission rates on an individual A-unit basis will be a good indication that groups of these A-units will give high recognition performance, and it is planned in the near future to determine the extent to which this is indeed true. This will be done by writing a program for measuring A-unit transmission rates, which can be used in conjunction with the present perceptron implementation programs.

2.5 Implementation

A preliminary literature survey has been made to study in more detail various techniques potentially useful for the implementation of the photo interpretation task. An attempt has also been made to define in more detail the general design requirements, considering such factors as image resolution, picture processing rate, number of response classes, and the implementation cost. An annotated bibliography on photo interpretation implementation has been prepared.

3.0 PLANS FOR AUGUST

3.1 Object Detection

The computer program discussed in Section 2.2 will be completed in August. Several different filters will be designed and applied to selected aerial

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[2] Lewis, P.M., "The Characteristic Selection Problem in Recognition Systems," I.R.E. Transactions of Information Theory, Vol. IT-8, Feb. 1962, pp 171-178

photographs. Examination of these results is expected to guide further research in the applicability of linear filtering to object detection.

3.2 Whole-Photo Classification

This activity is expected to be similar to that of Section 3.1. The filter characteristics to be investigated will be chosen to match the needs of whole-photo classification.

3.3 Recognition

Coding of the program mentioned in Section 2.4 for measuring A-unit transmission rates will be begun during August. This program will accept as input a tape describing A-unit activity, which is produced by the first of two programs currently used for implementing the perceptron on the 704. This tape would normally contain several different types of A-units representing different combinations of parameters, with a number of A-units of each type. The new program will output the transmission rate of each A-unit, with respect to the patterns being classified, and also the average transmission rate for each type of A-unit.

3.4 Implementation

In the near future it is planned to:

1) Continue literature survey on a limited basis; this includes several
 quarterly reports by [redacted] on Graphical Data Processing Research, and
 also [redacted] research reports.

2) Outline and describe several system designs in enough detail to estimate process rates, efficiency, and applicability to the project needs. Examples include:

a. Spatial optical prefilter (fixed or band swept) coupled with electro-optical perceptive or deterministic classifier.
b. Positive-negative (Herschel) film storage to enhance objects with a programmable recognizer.
c. Optical parallel processor-recognizer.

4.0 REPORTS

No reports other than the regular monthly letter report were published during the last month.